Digital tools and 3D printing technologies integrated into the workflow of restorative treatment: A clinical report

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Abstract: The development of technologies including intraoral scanners, dental software for digital restoration design, and additive manufacturing has improved the digital workflow of restorative treatment. The present article describes a digital workflow with intraoral scanning, computer-aided design (CAD) software, and subtractive and additive manufacturing procedures for a patient receiving lithium disilicate laminate veneers.

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TITLE

Potential use of digital tools and 3D printing technologies integrated in the workflow of restorative treatment

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ABSTRACT

The development of the latest technologies likewise intraoral scanner, dental software for the digital design of restorations and additive manufacturing technologies is allowing the gradual incorporation of new protocols to implement the digital workflow in the restorative treatment. Even though the digital procedures conceptually do not differ to the conventional, the understanding of the digital tools, exceeding a learning curve and training the dental team into the digital workflow are some key steps to implement and maximize the latest technologies on the restorative treatments. The present article describes a veneer digital workflow case report, where the incorporation of the intraoral scanner procedures, the digital tools of the CAD software and subtractive and additive manufacturing procedures were employed.

INTRODUCTION

Three fundamental steps that compose the digital workflow for dental applications are (1) data acquisition or digitalization, (2) data processing (CAD) and (3) manufacturing (CAM).[1-5]

Data can be obtained from a range of different sources such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), extraoral (contact or laser) or intraoral scanner. The introduction of the intraoral scanning devices has minimized the human manipulation decreasing the processing errors, saving time and costs.[6-8] Moreover, digital impressions has reported a better acceptance by patients.[9,10] The scan strategy[11,12] and the learning curve[13] using such devices are essential on the final outcome.

The accuracy of a digitizer should be defined by two parameters: trueness and precision (ISO 5725- 1, DIN 55350-13).[14] Trueness relates on the capacity to digitize an object as closely as its true form, meanwhile precision means reproducibility or the degree to digitize an object identically by repeated scanning under the same conditions.[15] Studies have reported high levels of accuracy with no significant difference between the measurements on dental stone and digital models.[16-20] Moreover, dental restorations fabricated with digital impression techniques exhibited similar marginal and internal gap to those fabricated with conventional impression techniques.[21]

The data obtained after digitizing is represented by a point cloud. Data processing involves the mathematical algorithms calculations to remove the aberrant points and optimize the density of the point cloud information. This triangulation method obtains a mesh which will be interpreted as a 3D model of the scanned object.[22]

As an alternative to the subtractive methods, additive manufacturing (AM) technologies provide manufacturing procedures in which the powder or liquid base material is built into a solid object.[23-28]

The present article describes a veneer complete digital workflow case report, where the incorporation of the intraoral scanner procedures, the digital tools of the CAD software and subtractive and additive manufacturing procedures were employed.

CLINICAL REPORT

A 58 years old patient was presented by himself for aesthetic treatment at a private practice. The anamnesis disclosed a healthy general condition. The extraoral examination revealed a not coincident facial and dental midline, a not coincident maxillary and mandibular dental midline, medium lip line, concave smile line and 0 mm of tooth visibility at rest. The clinical examination showed an acceptable oral health where no periodontal probing depth of more of 3 mm were encountered but generalized moderate periodontitis, localized gingival recessions and disproportionate gingival levels were noted. The maxillary anterior teeth presented composite restorations with defective integrity of the margins and colour disharmony with the adjacent teeth. Also, metal-ceramic fixed dental prostheses (FPD) were present on the majority of the posterior teeth with an adequate integrity of the margin but porcelain chipping was observed on the left second mandibular molar. The patient presented over-erupted and decreased mesio-distal width of the maxillary and mandibular anterior teeth, with wear facets due to parafunctional habits. The occlusal plane was altered and the antero-posterior compensating curve was exaggerated.

Extraoral and intraoral photographs (Fig. 1A-C), videos, radiographs (Fig. 2) and a digital impression was made using an intraoral scanner (TRIOS 3 intraoral scanner; 3Shape) following the manufacturer´s scanning protocol. Treatment options were presented and, despite the benefits that could be obtained from an interdisciplinary full-mouth treatment with orthodontic, periodontal and prosthodontic rehabilitation, the patient elected to restore only the maxillary anterior teeth. The objectives of the selected treatment option were to increase the tooth visibility at rest, change the concave smile line, level de gingival margins of the maxillary anterior teeth, cover the root exposure Miller class III of the maxillary canines as much as possible and replace the defective composite restorations of the maxillary anterior teeth.

A digital diagnostic wax-up was prepared using a specific software (Dental System; 3Shape) importing the direct connection mode (DCM) file obtained from the digital impression (Fig. 3AB). The diagnostic tools of the CAD software were used to measure the amount of volume added on the incisal and buccal of the virtual wax-up teeth and the amount of gingivectoy/crown lengthening virtually designed on the maxillary anterior teeth. The length of the maxillary central incisors was increased 1.17 mm and the volume added on the buccal surface of the maxillary anterior teeth range from 0.4 to 1.2 mm. Moreover, specific software (RealView Dental System; 3Shape) was used to superimpose the digital diagnostic wax-up into the patient´s photographs (Fig. 4A-B). When this process was completed, a standard tessellation language (STL) file of virtual wax-up was exported.

A digitally designed silicone index was prepared using a specific software (Dental System; 3Shape) and additive manufactured (D30 RapidShape; RapidShape) using clear flexible photopolymer resin (Ortho IBT Clear; Nexdent Vertex Dental) (Fig. 5A-B). The buccal finishing line of the silicone index was virtually determined on the new gingival margin of the maxillary anterior teeth and a uniform 8 mm thickness of the index was prepared. A diagnostic mock-up was prepared using the 3D printed silicone index and an interim composite resin material (Protemp 4 A2; 3M ESPE). The aesthetic appearance, function and phonetics were confirmed (Fig. 6A-C),[29,30] in which no modifications of the diagnostic mock-up were needed.

The gingivectomy and crown lengthening of the teeth #7, 8, 9 and 10 was accomplished by a private periodontist, using the diagnostic mock-up as a reference. A free connective tissue graft was performed to coverage the buccal root exposure on teeth 6 and 11. The healing was followed up to 9 months' post-surgery.

Before the veneer tooth preparation of the maxillary anterior teeth, the defective composite restorations of the maxillary anterior teeth were replaced achieving the tooth dimensions of the digital diagnostic wax-up, in order to evaluate the function, phonetic and aesthetic for 3 months. A digital impression of the maxillary (pre-preparation scan) and mandibular (antagonist scan) arches and interocclusal relationship (occlusal scan) was made using the same intraoral scanner following the manufacturer´s scanning protocol (Fig. 7A-C). The diagnostic restorations were employed to prepare the maxillary anterior teeth for a lithium disilicate milled veneer restorations[31,32] using a medium grit and fine grain diamond burs (868.314.012/016, 8868.314.012/016 Bur; Komet Dental), the angles were rounded with polishing discs (Sof-lex XT Discs; 3M ESPE). A double displacement cords (000, 00 Ultrapack Retraction Cord; Ultradent) were packed and the digital impression of the prepared tooth (preparation scan) was made using the same intraoral scanner device (Fig. 8A). The absence of undercuts on the veneer preparations and the restorative interocclusal space was verified using the intraoral scanner software and sent it to the dental laboratory through the internet connection. The 3D printed silicon index and a composite resin provisional material (Protemp 4 A2; 3M ESPE) was applied to the preparations to fabricate the provisional restorations (Fig. 8B).

The monolithic lithium disilicate veneer restorations were designed using the specific software (Dental System; 3Shape). The diagnostic restorations acted as reference and scanned as pre-preparation that provided the information of the dental maxillary midline, shape, dimensions and position of the maxillary anterior teeth. When the design was completed, the STL file was exported and used to manufacture the milled (Zenotec Select Hybrid Wieland; Ivoclar Vivadent) lithium disilicate restorations (IPS E.max CAD LT-A2 ingots; Ivoclar Vivadent). The same STL file was used to prepare the maxillary and mandibular master casts using the specific software (Model Builder; 3Shape). The casts were fabricated using a DLP

AM technology (D30 RapidShape; RapidShape), with a 25 µm layer thickness of photopolymer (Nexdent Model, Oker colour; Nexdent Vertex Dental).

On the delivery appointment, the provisional restorations were carefully removed, and the teeth were cleaned with a prophylaxis brush (1102F.204.060 Fine Prophylaxis brush; Jota AG) and pumice paste (Topex Prep & Polishing Paste; Sultan Healthcare). The veneer restorations were tried (RelyX Veneer Try-in TRT; 3M ESPE) on the patient´s teeth to verify the marginal fit, proximal contact points and the colour integration with the adjacent teeth. The ceramic veneer restorations were delivered with a polymerized cement (RelyX Veneer Cement Translucent; 3M ESPE) (Fig. 9A-C). A radiographical evaluation was completed after the restorations were delivered (Fig. 10A-C) and the patient was introduced in an annual revision protocol.

DISCUSSION

Furthermore, the digital tools offer a more efficient diagnostic information for instance the 3D measurements of the virtual wax-up thicknesses giving the amount of tooth reduction needed or the available restorative space.[33,34] Another feature of some CAD software is the alignment of the 3D virtual wax-up on a 2D photography of the patient which can be used as a communication tool, nevertheless, the diagnostic mock-up represents a more realistic materialization providing a tentative outcome of the treatment on the patient´s mouth.[35-38,42] The flexible clear polymer resin was fabricated with AM which connects the virtual diagnostic wax-up and the patient´s mouth, so the 3D printing of the cast can be avoided.

Polymer AM technologies also allow the materialization of the master casts for the veneer manufacturing process.[26,28] Through the specific CAD software a solid or alveolar master cast can be prepared and manufactured. However, on the reported clinical case a monolithic lithium disilicate veneer restorations were selected, so the master cast could have been avoided as the interproximal and occlusal contact points are designed and manufactured with the CAD-CAM procedures. The master casts are however fundamental when a buccal cut back is designed on the ceramic veneers.

SUMMARY

The present article describes a veneer complete digital workflow case report, where the incorporation of the intraoral scanner procedures, the digital tools of the CAD software and subtractive and additive manufacturing procedures were employed.

REFERENCES

1. Young JM, Altschuler BR. Laser holography in dentistry. J Prosthet Dent 1977;38:216-25.

2. Kalpakjian S, Schmid SR. Manufacturing engineering and technology. 7th Edition. Addison-Wesley, New York; 2014. p. 1-10.

3. Van Noort R. The future of dental devices is digital. Dent Mater 2012;28:3-12.

4. Horn TJ, Harrysson OLA. Overview of current additive manufacturing technologies and selected applications. Sci Prog 2012;95:255-82.

5. Al-Jubouri O, Azzari A. An introduction to dental digitizers in dentistry: systematic review. J Chem Pharm Res 2015;7:10-20.

6. Christensen GJ. Impressions are changing: Deciding on conventional, digital or digital plus in-office milling. J Am Dent Assoc 2009;140:1301-4.

7. Joda T, Brägger U. Digital vs. conventional implant prosthetic workflows: a cost/time analysis. Clin Oral Impl Res 2015;26:1430-5.

8. Lee JS, Gallucci GO. Digital vs. conventional implant impressions: efficiency outcomes. Clin Oral Implants Res 2013;24:111-5.

9. Wismeijer D, Mans R, van Genuchten M, Reijers HA. Patients' preferences when comparing analogue implant impressions using a polyether impression material versus digital impressions (Intraoral Scan) of dental implants. Clin Oral Impl Res 2014;25:1113-8.

10. Joda T, Brägger U. Patient-centered outcomes comparing digital and conventional implant impression procedures: a randomized crossover trial. Clin Oral Impl Res 2016;27:e185-9.

11. Anh JW, Park JM, Chun YS, Kim M, Kim M. A comparison of the precision of three-dimensional images acquired by 2 digital intraoral scanners: effects of tooth irregularity and scanning direction. Korean J Orthod 2016;46:3-12.

12. Müller P, Joda T, Katsoulis J. Impact of digital intraoral scan strategies on the impression

accuracy using the TRIOS Pod scanner. Quintessence Int 2016;47:343-9.

13. Kim J, Park JM, Kim M, Heo SJ, Shin IH, Kim M. Comparison of experience curves between two 3-dimensional intraoral scanners. J Prosthet Dent 2016;116:221-30.

14. Normung DDlf. Accuracy (trueness and precision) of measurement methods and results - Part 1: General principles and definitions (ISO 5725-1:1994). Berlin: Beuth Verlag GmbH; 1997.

15. Keating AP, Knox J, Bibb R, Zhurov AI. A comparison of plaster, digital and reconstructed study model accuracy. J Orthod 2008; 35:191-201.

16. Cuperus AMR, Harms MC, Rangel FA, Bronkhorst EM, Schols JGJ, Beruning KH. Dental models made with an intraoral scanner: A validation study. Am J Orthod Dentofacial Orthop 2012;142:308-13.

17. Patzelt SB, Emmanouilidi A, Stampf S, Strub JR, Att W. Accuracy of full-arch scans using intraoral scanners. Clin Oral Investig 2014;18:1687-94.

18. Ender A, Mehl A. In-vitro evaluation of the accuracy of conventional and digital methods of obtaining full-arch dental impressions. Quintessence Int 2015;46:9-17.

19. Aragon MLC, Pontes LF, Bichara LM, Flores-Mir C, Normando D. Validity and reliability of intraoral scanners compared to conventional gypsum models measurements: a systematic review. Eur J Orthod 2016;38:429-34.

20. Goraci C, Franchi L, Vichi A, Ferrari M. Accuracy, reliability, and efficiency of intraoral scanners for full-arch impressions: a systematic review of the clinical evidence. Eur J Orthod 2016;38:422-8.

21. Chochlidakis KM, Papaspyridakos P, Geminiani A, Chen CJ, Feng IJ, Ercoli C. Digital versus conventional impressions for fixed prosthodontics: A systematic review and meta-analysis. J Prosthet Dent 2016;116:184-90.

22. Budak I, Vukelić D, Bračun D, Hodolič J, Soković M. Pre-processing of point-data from contact and optical 3D digitization sensors. Sensors 2012;12:1100-26.

23. ASTM, Committee F42 on Additive Manufacturing Technologies, West Conshohocken, Pa. 2009 Standard terminology for additive manufacturing – general principles and terminology. ISO/ASTM52900-15.

24. Azari A, Nikzad S. The evolution of rapid prototyping in dentistry: a review. Rapid Prototyping J 2009;15:216-25.

25. Sun J, Zhang FQ. The Application of Rapid Prototyping in Prosthodontics. J Prosthodont 2012;21:641-4.

26. Stansbury JW, Idacavage MJ. 3D printing with polymers: Challenges among expanding options and opportunities. Dent Mater 2016;32:54-64.

27. Abduo J, Lyons K, Bennamoun M. Trends in computer-aided manufacturing in prosthodontics: a review of the available streams. Int J Dent 2014;2014:783948.

28. Revilla-León M, Sánchez-Rubio JL, Oteo-Calatayud J, Özcan M. Impression technique for a complete-arch prosthesis with multiple implants using additive manufacturing technologies. J Prosthet Dent 2017;117:714-20.

29. Magne P, Magne M, Belser U. The diagnostic template: a key element to the comprehensive esthetic treatment concept. Int J Periodontics Restorative Dent 1996;16:560-9.

30. Magne P, Magne M, Belser U. Natural and restorative oral esthetics. Part I: Rationale and basic strategies for successful esthetic rehabilitations. J Esthet Dent 1993;5:161-73.

31. Gurel G. The science and art of porcelain laminate veneers. Chicago: Quintessence Publishing Co; 2003. p. 43-54.

32. Magne P, Belser UC. Novel porcelain laminate preparation approach driven by a diagnostic mock-up. J Esthet Restor Dent 2004;16:7-18.

33. Seelbach P, Brueckel C, Wostmann B. Accuracy of digital and conventional impression techniques and workflow. Clin Oral Investig 2013;17:1759-64.

34. Syrek A, Reich G, Ranftl D, Klein C, Cerny B, Brodesser J. Clinical evaluation of all-ceramic crowns fabricated from intraoral digital impressions based on the principle of active wavefront sampling. J Dent 2010;38:553-9.

35. Magne P, Magne M, Belser U. The diagnostic template: a key element to the comprehensive esthetic treatment concept. Int J Periodontics Restorative Dent 1996;16:560-9.

36. Simon H, Magne P. Clinically based diagnostic wax-up for optimal esthetics: the diagnostic mock-up. J Calif Dent Assoc 2008;36:355-62.

38. Patzelt SB, Vonau S, Stampf S, Att W. Assessing the feasibility and accuracy of digitizing edentulous jaws. J Am Dent Assoc 2013;144:914-20.

38. Ender A, Mehl A. Influence of scanning strategies on the accuracy of digital intraoral scanning systems. Int J Comput Dent 2013;16:11-2.

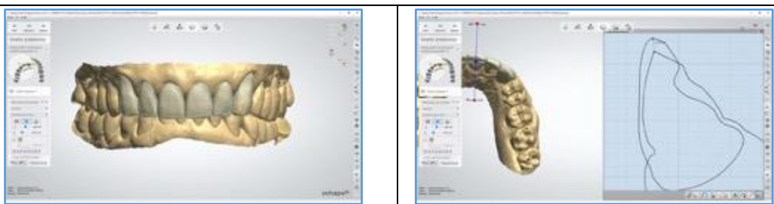
FIGURES

Figs. 1A-C. A, Lower third frontal extraoral photographic record at rest, B, Smile position of the lower third of the patient, C, Frontal view of the maxillary and mandibular arches.

A)	B)	C)

Figs. 2. Radiographic initial evaluation.

Figs. 3A-B. A, Diagnostic virtual wax-up of the maxillary anterior teeth, B, Measurement of the amount of coronal lengthening of maxillary left central incisor achieved with the virtual diagnostic wax-up.



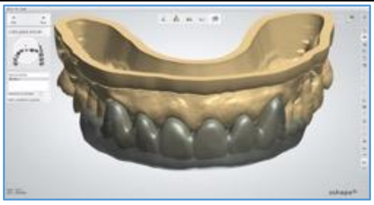
A)	B)

Figs. 4A-B. Virtual simulation of the 3D digital diagnostic wax-up on a 2D photograph of the patient, using a specific dental software (RealView Dental System; 3Shape). A, Rest position and, B, Smile position of the lower third of the patient’s face.

A)

B)

Figs. 5A-B A, Virtual design of a silicon index using a specific dental software (Dental System, 3Shape), B, 3D printed flexible clear polymer index (Ortho IBT; Vertex NexDent).



A)

B)

Figs. 6A-C. A, Try-in of the additive manufactured silicone index on the patient’s mouth, B, Rest position and C, Smile position with the diagnostic mock-up.

A)

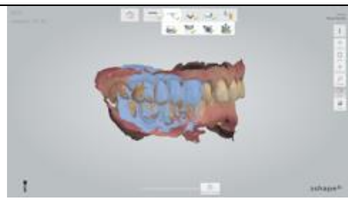
B)

C)

Figs. 7A-C. A, Digital impression of the diagnostic mock-up (pre-preparation scan), B, Digitalization of the mandibular arch (antagonist scan), C, Interoclusal record (occlusal scan) was completed using an intraoral scanner device (TRIOS 3 intraoral scanner; 3Shape).


A)


B)


C)

Figs. 8A-B. A, Digital impression of the tooth preparation of the maxillary anterior teeth (preparation scan) using the same intraoral scanner (TRIOS 3 intraoral scanner; 3Shape), B, Composite interim restorations on the maxillary anterior teeth.


A)


B)

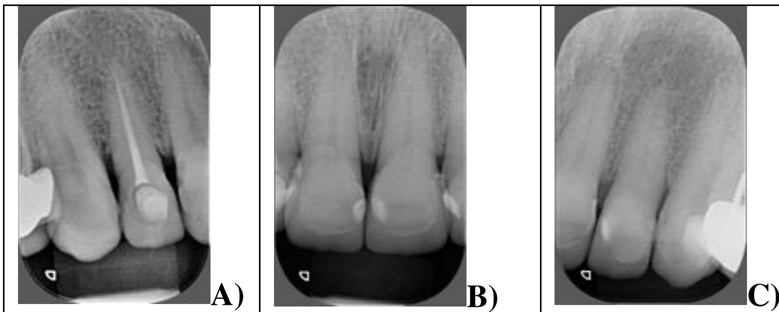
Figs. 9A-C. A, Facial frontal extraoral photographic record at rest, B, At smile position of the patient, C, Frontal view of the cemented lithium disilicate veneer restorations.


A)


B)


C)

Fig. 10A-C. Periapical radiographs with the ceramic veneers delivered, A, Maxillary right canine and lateral, B, Maxillary right and left central incisors and C, Maxillary right lateral and canine teeth.



A) B) C)